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SALINITY AND THE STRUCTURE OF BENTHIC ALGAE (PERIPHYTON) COMMUNITIES IN STREAMS OF THE SOUTHERN FORT UNION REGION, MONTANA

Prepared for the

Bureau of Land Management

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ABSTRACT

Nearly 300 periphyton (benthic algae) samples were collected from 32 streams and two ponds in the southern Fort Union coal region of Montana from May 1978 to November 1979. Collections were analyzed for key structural parameters of the periphyton community. Most periphyton collections were accompanied by a measurement of specific conductance.

Most streams in the study area supported healthy periphyton communities dominated by diverse associations of diatoms, indicating these streams and communities were relatively free from excessive stress, i.e., pollution. Streams of the study area varied considerably in the composition of their benthic diatom associations. Within the normal range of specific conductance values encountered (239 µmhos to 6,400 µmhos), salinity did not appear to have an overriding or adverse effect on the structure of periphyton communities. Other factors besides salinity influence the structure and composition of periphyton communities. The critical threshold level above which salinity will impair the structure of periphyton communities of the study area is unknown, but it is believed to be in excess of 7,500 µmhos.

The effects of saline seeps on diatom diversity are discussed, as well as the effects of salinity on other beneficial uses. Recommendations are made regarding salinity control, salinity and biological monitoring, and additional research.

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INTRODUCTION

This report presents the findings of the periphyton portion of a greater biological-benthic study of streams in the southern Fort Union region of Montana (U.S.G.S. Grant No. 14-08-0001-G-503). Objectives of the study were (1) to obtain biological data on periphytic and macroinvertebrate components of stream benthos at selected sites in the southern part of the Fort Union coal region and (2) to assess the effects of salinity on stream biota. The study attempted to provide information on potential effects of increased salinity resulting from mining activities on stream biota.

Except in the lower reaches of Montana's largest rivers, the stream periphyton (bottom) community is more important than the stream plankton (open water) community in terms of plant diversity and production. The importance of the periphyton communities in streams draining energy resource areas of Montana and the Rocky Mountain West is underscored by their inclusion in ecological baseline studies required by the Montana Department of State Lands and recommended by the U.S. Fish and Wildlife Service (States *et al.*, 1978).

In unpolluted waters, the dominant periphyton algae are diatoms. Diatoms are microscopic, golden-brown plants encased in silica. They are the preferred food of many aquatic invertebrates. When a river or creek is polluted and its chemical and biological equilibrium is disturbed, diatoms often are displaced by coarser, less palatable green and blue-green algae (Patrick, 1978). Generally, the lower diatoms are ranked, the more polluted and ecologically unbalanced is the river or creek.

Clean waters usually have many different diatom species; some species may be fairly common but none really are dominant. Polluted waters have fewer species, often with one or two species very abundant. Clean water is said to have high diversity and polluted water is said to have low diversity. Diversity can be measured simply by counting the number of species in a sample or by more elaborate methods, including calculation of rather involved formulas called diversity indexes.

This report is one of three produced by the Montana Department of Health and Environmental Sciences to consummate the U.S.G.S./B.L.M. biological-benthic study. A companion report addresses salinity and the structure and composition of macroinvertebrate communities in streams of the southern Fort Union region. The third report, a detailed compilation of data gathered over the course of the study, serves as an appendix to the first two volumes.

The field segment of this study commenced in May 1978 and ended in November 1979.

DESCRIPTION OF THE STUDY AREA

The study area is roughly that portion of the Fort Union region in Montana south of the Yellowstone River (Figure 1). The area extends from the Sarpy Creek drainage on the west to the Powder River drainage on the east. The southern boundary of the study area matches the Montana-Wyoming border except for a slight ingression into Wyoming up the Tongue River drainage to near the mouth of Ash Creek north of Sheridan.

The entire study area is within the Yellowstone River Basin and includes portions of the Tongue and Powder river drainages, the drainage of Rosebud Creek, and those of several small tributaries to the Yellowstone River between Hysham and Miles City. Forty-three stations were sampled on 32 rivers and creeks and two standing waters. Each flowing water station consisted of a stream reach up to several miles long. Nine stations on eight significant streams were selected for intensive seasonal analysis (Table 1).

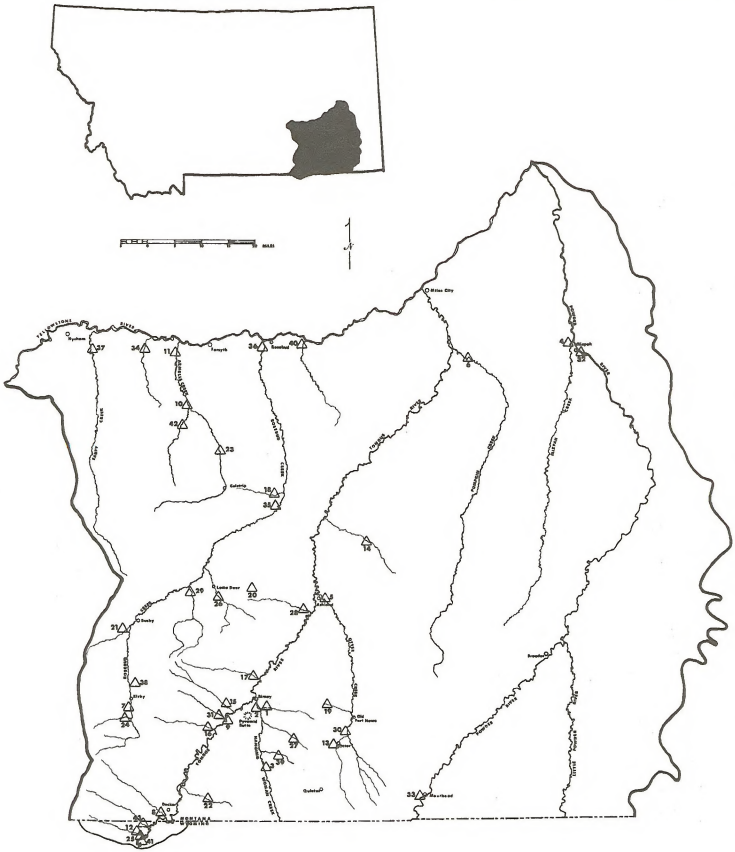

Figure 1. Map of the southern Fort Union region in Montana showing locations of sampling stations for the biological-benthic study.

Table 1. Sampling stations and the number of periphyton collections from each station (in parentheses).

Map Number	Intensive Stations
1	East Fork Hanging Woman Cr. near Birney (19)
2	Hanging Woman Cr. near Birney (22)
3	Hanging Woman Cr. near Quietus (19)
4	Mizpah Cr. near Mizpah (13)
5	Otter Cr. near Ashland (19)
6	Pumpkin Cr. near Miles City (13)
7	Rosebud Cr. near Kirby (19)
8	Squirrel Cr. near Decker (19)
9	Tongue R. near Pyramid Butte (18)

Map Number	Accessory Stations
10	Armells Cr. near Colstrip (1)
11	Armells Cr. near Forsyth (5)
12	Ash Cr. near Sheridan, Wyoming (3)
13	Bear Cr. near Otter (2)
14	Beaver Cr. near Ashland (7)
15	Bull Cr. near Birney (2)
16	Canyon Cr. near Pyramid Butte (4)
17	Cook Cr. near Birney (4)
18	Cow Cr. near Colstrip (1)
19	Cow Cr. near Fort Howe (3)
20	Crazy Head Springs (pond) near Ashland (1)
21	Davis Cr. near Busby (4)
22	Deer Cr. near Decker (4)
23	East Fork Armells Cr. near Colstrip (3)
24	Indian Cr. near Kirby (9)
25	Interstate Ditch near Sheridan, Wyoming (1)
26	Lame Deer Cr. near Lame Deer (5)
27	Lee Cr. near Birney (1)
28	Logging Cr. near Ashland (5)
29	Muddy Cr. near Busby (6)
30	Otter Cr. near Otter (7)
31	Prairie Dog Cr. near Birney (3)
32	Powder R. near Mizpah (0)
33	Powder R. near Moorhead (1)
34	Reservation Cr. near Forsyth (7)
35	Rosebud Cr. near Colstrip (5)
36	Rosebud Cr. near Rosebud (4)
37	Sarpy Cr. near Hysham (6)
38	Slough near Kirby (1)
39	Stroud Cr. near Quietus (3)
40	Sweeney Cr. near Rosebud (6)
41	Tongue R. near Sheridan, Wyoming (4)
42	West Fork Armells Cr. near Colstrip (4)
43	Youngs Cr. near Sheridan, Wyoming (5)

METHODS

Field Methods

Specific Conductance

Because of greater ease and economy of analysis, specific conductance was used as a surrogate measure of salinity in this study. Unpreserved and unfiltered grab samples were collected in one-liter plastic bottles and transported back to the laboratory at the Billings Branch Office of the Department of Health and Environmental Sciences. Water samples for measurement of specific conductance were collected concurrent with most periphyton collections.

Periphyton

Two hundred and eighty-eight (288) collections of benthic algae were made during the study. To meet different study objectives, algae were collected in four different ways as described below. Constraints imposed by time and the depauperate nature of some collections dictated that laboratory analyses would be conducted to different levels of detail, to be explained further under "Laboratory Methods--Periphyton." Table 2 aggregates the number of collections by sampling method and level of analytical detail.

Generally, conspicuous soft-bodied algae were plucked by hand. Diatoms and less conspicuous soft-bodied algae were scraped or lifted from their substrates with a sharp-edged tool, such as a pocket knife, single-edged razor blade, or scalpel. Specimens were placed in vials or small jars containing ambient water and preserved with Lugol's (IKI) solution (A.P.H.A., 1975).

Table 2. Number of periphyton collections aggregated by sampling method and level of analytical detail.

Selective Collections of Soft-bodied Algae	22
Selective Collections of Diatoms for Semi-detailed Readings	10
Composite Collections from Natural Substrates	218
Analysis of Soft-bodied Algae Only (91)	
Analysis of Soft-bodied Algae plus Diatoms (127)	
Short Diatom Proportional Counts (14)	
Long Diatom Proportional Counts (113)	
Composite Collections from Artificial Substrates (Plexiglas)	38
Short Diatom Proportional Counts (2)	
Long Diatom Proportional Counts (36)	
Total Collections	288

Selective Collections of Soft-bodied Algae. These collections were made for the sole purpose of identifying the algae responsible for conspicuous attached or floating growths. They were strictly qualitative in nature and used only to round out the list of non-diatom algae encountered in the study area.

Selective Collections of Diatoms. Exhaustive diatom collections were made at the nine intensive stations plus one accessory station (Indian Cr.) for the purpose of detailed comparisons of diatom community structure. Collections were made in August (1979)--the month of maximum diatom diversity in certain Montana waters (Bahls, 1973). Diatoms were collected from each substrate roughly in proportion to the substrate's importance at a station. Soft-bodied algae were collected only as they

might serve as substrates for diatoms. An attempt also was made to sample diatoms subjected to different levels of current velocity, depth, and shading. The ultimate objective was to obtain a replicate, in miniature, of the *in situ* diatom association.

Composite Collections from Natural Substrates. These collections were made in much the same way as the selective collections of diatoms, except that both diatoms and soft-bodied algae were sampled. Conspicuous soft-bodied algae were collected in proportion to their importance relative one to another and to the diatom association as a whole. The ultimate objective was to obtain a replicate, in miniature, of the total periphyton community. This type of collection accounted for the bulk of the samples (218) in this study. At intensive stations, these collections were made at various times throughout the ice-free season (February-November). At accessory stations, they were made primarily during the summer months (June-September).

Composite Collections from Artificial Substrates. These collections were made at intensive stations to compare periphyton communities from natural substrates to those colonizing the Plexiglas plates used for standing crop estimates. Plates were exposed for at least one month prior to sampling. Periphyton growths, including diatoms and soft-bodied algae, were scraped from areas on the plates not used for chlorophyll measurements. For the purposes of this report, collections from Plexiglas plates will be used only to supplement the taxonomic list and to bolster rank, abundance, and frequency statistics for algae in the study area (Table 4). An evaluation of the effect of substrate on periphyton structure, as well as the effect of other non-salinity factors, will be reserved for a subsequent report pending funding from the U.S. Geological Survey.

Specific Conductance

Specific conductance was measured at the Billings water quality laboratory of the Montana Department of Health and Environmental Sciences with a Lab-Line "Lectro Mho-Meter," Model MC-1, Mark IV.

Periphyton

Just prior to processing, the sample container was agitated vigorously to attempt to dislodge diatoms from their algal substrates and to initiate randomization of diatom frustules.

Analysis of Soft-bodied Algae. Conspicuous soft-bodied algae were removed individually from the sample container, examined microscopically, and identified to genus. (Table 3 illustrates a classification scheme for the algae and shows the different levels of taxonomic identification using a diatom example.) The remainder of the sample was again shaken and a small subsample was quickly pipetted with a soda straw onto a clean glass microscope slide. The subsample was covered with a coverslip and scanned until the majority of the less conspicuous soft-bodied algae were located and identified. The relative abundance and rank by volume of each soft-bodied genus and the diatom association as a whole were then estimated and recorded. Five categories of abundance were employed: very abundant, abundant, very common, common and rare.

Diatom Proportional Counts. The remainder of the sample was then used to prepare a permanent, randomly strewn diatom mount using sulfuric acid and potassium dichromate as the oxidizing agents and Cargille's "Carmount-165" as the mounting medium (A.P.H.A., 1975). A diatom proportional count was performed on each slide following the technique outlined by Weber (1973), except that in excess of 300 rather than 250

cells were tallied. Such counts, generally between 300 and 400 cells, are called "long counts." In a small percentage of the samples there were insufficient diatoms to conduct a long count within a reasonable length of time. These collections were subjected to a "short count" of between 100 and 200 cells.

Diatom proportional counts were performed on all composite collections from intensive stations and on at least one composite collection from each of the accessory stations. Because of time constraints (each proportional count requires 2 to 6 hours), 91 composite collections from natural substrates at accessory stations were not processed beyond analysis of the soft-bodied algae.

Diatoms were identified to the variety level and tabulated at the species level (Table 3).

Table 3. A classification scheme for the algae with a diatom example (Patrick and Reimer, 1966).

Division (Phylum)	Bacillariophyta
Class	Bacillariophyceae
Order	Fragilariales
Family	Fragilariaceae
Subfamily	Fragilarioideae
[1]Genus	*Synedra*
Subgenus	*Synedra*
[2]Species	*ulna*
[3]Variety	*oxyrhynchus*
Form	*mediocontracta*

[1] Level to which soft-bodied algae were identified
[2] Level at which diatoms were tabulated
[3] Level to which diatoms were identified

"Semi-detailed Readings." Semi-detailed readings were performed on selective diatom collections taken from the intensive stations and Indian Creek during the week of August 5, 1979. The purpose of the semi-detailed readings was to gain in-depth statistical knowledge of the structure of the intensive station diatom associations and to allow for rigorous comparisons among them. Semi-detailed readings followed the procedure outlined by Hohn (1961).

Diatom slides (strewn mounts) for the semi-detailed readings were prepared in much the same way as they were for the standard proportional counts, except that emphasis was placed on achieving a uniform distribution of cells across the coverslip. The first row across the coverslip was read as a proportional count in that each cell was identified and tabulated. Thereafter, additional rows were scanned and new taxa were recorded until a *minimum* of 8,000 cells (estimated) were examined, compared to only 300 to 400 cells for a long diatom proportional count.

Derived Statistical Measures

Shannon-Weaver Diversity ($\bar{d}$). The results of the diatom proportional counts were used to compute percent relative abundance of diatom species and diatom species diversity using the Shannon-Weaver formula recommended by Weber (1973):

$$\bar{d} = \frac{C}{N}(N \log_{10} N - \Sigma\, n_i \log_{10} n_i)$$

where C = 3.321928; N = total number of cells counted; and n_i = number of cells in the i^{th} species. Bahls (1979) found that benthic diatom associations in unpolluted Montana streams usually had more than 25 species and $\bar{d}$ values greater than 3.00. Species numbers significantly less than 25 and diversity values significantly below 3.00 may be indicative of pollution.

RESULTS

Specific Conductanace

The average of 200 specific conductance measurements made in conjunction with composite periphyton collections from natural substrates was 2,260 µmhos. All but one of the specific conductance values ranged from 239 µmhos to 6,400 µmhos. The one outlier of 11,000 µmhos was recorded at the upper Hanging Woman Cr. station (near Quietus). The lowest value (239 µmhos) was measured in the Tongue River near Sheridan.

Periphyton

All Stations

General Features. Forty-six (46) genera of soft-bodied algae were identified from the study area (Table 4). The most frequently occurring soft-bodied algae in the composite collections were *Cladophora, Phormidium, Oedogonium, Spirogyra, Oscillatoria, Audouinella, Vaucheria, Rhizoclonium, Stigeoclonium,* and *Mougeotia.* Although representatives were present from six divisions and eight classes of non-diatom algae, green and blue-green algae predominated in terms of number of genera and frequency of occurrence. The number of soft-bodied genera in composite collections from natural substrates averaged 2.8 and ranged from 0 to 12.

Forty-two (42) genera of diatoms were identified from the study area, including at least 409 varieties. Diatoms were encountered in all of the composite collections and had the highest mean rank of all the algae (Table 4). The number of diatom species in composite collections from natural substrates averaged 39 and ranged from 17 (Squirrel Cr.) to 77 (Hanging Woman Cr. near Birney). Diatom species diversity ($\bar{d}$) among composite collections from natural substrates averaged 3.81 and ranged from 1.72 (Pumpkin Cr.) to 5.37 (Hanging Woman Cr. near Birney).

Percentage Similarity of Community Samples (PS_c). First-row proportional counts for the ten semi-detailed readings were used to compare diatom floristic affinities among the nine intensive stations and Indian Creek. The statistic used is termed percentage similarity of community samples (Whittaker and Fairbanks, 1958):

$$PS_c = 100 - 0.5 \Sigma \left| a - b \right|$$

where a and b are, for a given species, the percentages of samples A and B which that species represents. PS_c values may range from 0 (floras totally different) to 100 (floras identical).

Table 4. Percent frequency, mean rank, and mean abundance of soft-bodied algal genera and the diatoms as a group (Bacillariophyceae) in composite collections from natural and artificial substrates (n=256).

	Frequency %	Mean Rank	Mean Abundance[1]
Division Chlorophyta (Green Algae)			
Class Chlorophyceae			
Ankistrodesmus	4.3	3.7	4.6
Chaetophora	2.0	2.4	2.2
Cladophora	41.0	1.9	2.2
Closterium	9.7	4.7	4.7
[2]*Coelastrum*	**	**	**
Cosmarium	2.0	4.0	5.0
Enteromorpha	2.3	2.0	2.2
Hormidium	3.1	4.8	4.2
Microspora	0.4	2.0	2.0
[2]*Microthamnion*	**	**	**
Monostroma	0.4	2.0	2.0
Mougeotia	10.5	3.7	3.4
Oedogonium	21.0	4.1	3.9
Pediastrum	1.2	4.0	4.3
Planktosphaeria	0.4	3.0	5.0
Pleurotaenium	0.4	10.0	5.0
Rhizoclonium	12.1	2.7	2.7
Scenedesmus	4.7	4.3	4.8
Schizomeris	0.8	3.0	2.5
Spirogyra	20.2	2.6	2.8
Stigeoclonium	11.7	3.2	3.7

	Frequency %	Mean Rank	Mean Abundance[1]
Ulothrix	0.8	3.5	4.5
Zygnema	1.6	4.5	3.5
Class Charophyceae			
Chara	4.3	2.4	2.9
Division Euglenophyta (Euglenoid Algae)			
Class Euglenophyceae			
Euglena	3.1	4.8	4.0
[2]*Trachelomonas*	**	**	**
Division Bacillariophyta (Diatoms)			
Class Bacillariophyceae	100.0	1.5	2.2
Division Chrysophyta (Golden-brown Algae)			
Class Xanthophyceae			
Tribonema	6.6	4.2	3.6
Vaucheria	12.8	2.0	2.1
Class Chrysophyceae			
[2]*Dinobryon*	**	**	**
Division Pyrrophyta (Dinoflagellates)			
Class Dinophyceae			
[2]*Ceratium*	**	**	**
Peridinium	0.4	2.0	5.0
Division Rhodophyta (Red Algae)			
Class Rhodophyceae			
Audouinella	15.6	3.1	3.7

	Frequency %	Mean Rank	Mean Abundance[1]
Division Cyanophyta (Blue-green Algae)			
Class Cyanophyceae			
Agmenellum	2.3	5.0	4.5
Anabaena	6.2	4.8	4.9
Aulosira	0.4	3.0	3.0
Calothrix	2.3	5.3	4.2
Chroococcus	0.8	6.5	5.0
Lyngbya	2.3	4.7	3.5
Nostoc	1.6	4.2	2.8
Oscillatoria	16.0	3.9	4.1
Phormidium	30.0	3.3	3.8
Rivularia	1.6	2.5	3.2
Sphaerocystis	0.8	3.5	5.0
Spirulina	5.5	4.6	4.6
Tolypothrix	0.4	5.0	5.0
Trichodesmium	0.4	9.0	5.0

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1 Numerical values were assigned to abundance estimates as follows:
very abundant = 1
abundant = 2
very common = 3
common = 4
rare = 5

2 These genera were encountered only in selective collections of soft-bodied algae and not among the 256 composite collections from natural and artificial substrates.

Linear Correlation with Specific Conductance. Four key structural features of the periphyton community were selected to determine their degree of association with specific conductance by means of linear correlation analysis. The features chosen were number of non-diatom (soft-bodied) genera, rank of the diatom group by volume, number of diatom species, and diatom species diversity ($\bar{d}$). Only composite collections from natural substrates were used for linear correlation analysis. Concurrent specific conductance values were available for 200 composite collections from natural substrates. These 200 collections were used for number of non-diatom genera and diatom rank analyses. Of these same 200 collections, long diatom proportional counts were completed on 109 collections, which were used for number of diatom species and diatom diversity analyses.

Correlation coefficients (r) were computed between conductance and each of these four variables using the formula presented by Weber (1973). Tabular and computed t values were then used to determine if the r values were significantly different from 0.

All correlations with specific conductance were positive, but only those involving number of diatom species and diatom species diversity ($\bar{d}$) were significant (Table 5). It may be inferred from these results that specific conductance and the number of diatom species, and specific conductance and diatom species diversity ($\bar{d}$), varied together in a positive fashion. However, no statement can be made regarding cause-effect relationships between specific conductance and the two diatom variables.

Table 5. Simple correlation coefficients (r) comparing specific conductance with key structural features of the periphyton community.

Variable	n	r
Number of Non-diatom (Soft-bodied) Genera	200	0.076
Rank of Diatom Group by Volume	200	0.044
Number of Diatom Species	109	0.271[1]
Diatom Species Diversity ($\bar{d}$)	109	0.209[2]

[1] Significant at the 1% level
[2] Significant at the 5% level

Intensive Stations

Standard Analyses. Among the 200 composite collections from natural substrates used for linear correlation analyses, 86 were from the nine intensive stations. Salinity (specific conductance) values and key periphyton parameters for these nine stations were summarized in an attempt to gain insight into the structure of their benthic algae communities and into any salinity-periphyton relationships that may be evident (Tables 6 through 10).

The Tongue River station near Pyramid Butte had the lowest minimum (270 µmhos) and average (593 µmhos) specific conductance values of the nine stations. Upper Hanging Woman Creek near Quietus had the highest maximum (6100 µmhos) and average (4581 µmhos) values (Table 6).

There was very little variation in the number of soft-bodied genera, ranging from a minimum of none (0) at four stations to a maximum of 6 at four stations. The average number of soft-bodied genera ranged from 1.7 in Squirrel Creek to 3.2 in lower Hanging Woman Creek near Birney (Table 7).

There also was very little variation in the rank of the diatom group (Bacillariophyta) by volume. The highest rank was 1 at all stations and the lowest rank was either 2 or 3, but never lower. The average rank of diatoms by volume ranged within the narrow interval of 1.2 to 1.8 (Table 8).

There were much greater variations in the number of diatom species and in diatom species diversity values (Tables 9 and 10). On the average, there were nearly twice as many species (50) in lower Hanging Woman Creek near Birney than in Pumpkin Creek near Miles City (28). Nevertheless, none of the average values indicate significant environmental stress based on the criterion of 25 species (Bahls, 1979).

Much the same situation held for diatom species diversity, with the lowest average value at the Pumpkin Creek station (2.97) and nearly co-equal high values at the lower Hanging Woman Creek (4.27) and Mizpah Creek (4.32) stations. However, caution should be used in interpreting the Mizpah Creek results because of the extremely small sample size (3). While nearly all stations had minimum species diversity values indicating some environmental stress at least part of the year, only the Pumpkin Creek station had an *average* value less than the criterion of 3.00 for healthy diatom diversity (Bahls, 1979).

Bahls *et al.* (1979) proposed a more refined scale for appraising water quality based on diatom diversity:

Diatom Diversity ($\bar{d}$)	Water Quality
> 4.50	Excellent
3.50-4.50	Good
2.50-3.50	Fair
< 2.50	Poor

Using average diversity values, water quality at the intensive stations would be rated "good", except at the Pumpkin Creek station, where it would be rated "fair" overall.

"Semi-detailed Readings." Results of semi-detailed readings performed according to Hohn (1961) reveal significant differences in the structure of diatom associations at the nine intensive stations and Indian Creek (Table 11).

Of the 10 stations examined, Pumpkin Creek had the most depauperate diatom flora and the highest specific conductance reading (5998 µmhos). On the other hand, the Tongue River station had the most diverse diatom flora and the lowest specific conductance value (576 µmhos).

Between these extremes, the apparent inverse relationship between salinity and diatom diversity breaks down. Diatom associations at the three Hanging Woman Creek stations, which had specific conductance values ranging from 1357 µmhos to 4893 µmhos, had nearly identical structural characteristics. All three had more diverse diatom floras than two streams (Rosebud Creek and Indian Creek) with significantly lower salinity levels.

Percentage Similarity of Community Samples (PS_c). A matrix of floristic affinities among the nine intensive stations and Indian Creek is presented in Table 12. Station pairs with high PS_c values, hence high floristic affinities, are Rosebud/Indian (60), Mizpah/Pumpkin (59), lower Otter/lower Hanging Woman (57), and upper Hanging Woman/lower Hanging Woman (43). Notable among these pairs is the significantly higher similarity between lower Hanging Woman Creek and lower Otter Creek than between the two Hanging Woman Creek stations. Station pairs with low PS_c values, hence low floristic affinities, are Mizpah/Rosebud (3),

Mizpah/Indian (6), and Pumpkin/Rosebud (6). The most "unique" station, floristically, defined as having the lowest total of PS_c values, was Mizpah Creek. The most "typical" station, floristically, defined as having the highest total of PS_c values, was lower Hanging Woman Creek (near Birney).

Table 6. Number of observations, minimum, maximum, and average values for specific conductance at the nine intensive stations.

Station	n	Minimum	Maximum	Average
East Fork Hanging Woman Cr. near Birney	12	1290	1390	1333
Hanging Woman Cr. near Birney	12	2820	4100	3363
Hanging Woman Cr. near Quietus	10	3320	6100	4581
Mizpah Cr. near Mizpah	4	900	3700	2252
Otter Cr. near Ashland	11	2670	3310	2961
Pumpkin Cr. near Miles City	6	478	2580	1277
Rosebud Cr. near Kirby	10	721	950	863
Squirrel Cr. near Decker	9	1365	2550	1947
Tongue R. near Pyramid Butte	12	270	1030	593

Table 7. Number of observations, minimum, maximum, and average values for number of soft-bodied genera at the nine intensive stations.

Station	n	Minimum	Maximum	Average
East Fork Hanging Woman Cr. near Birney	12	1	6	2.9
Hanging Woman Cr. near Birney	12	1	6	3.2
Hanging Woman Cr. near Quietus	10	1	6	2.9
Mizpah Cr. near Mizpah	4	1	4	2.0
Otter Cr. near Ashland	11	0	6	2.5
Pumpkin Cr. near Miles City	6	0	5	2.3
Rosebud Cr. near Kirby	10	0	5	2.2
Squirrel Cr. near Decker	9	0	3	1.7
Tongue River near Pyramid Butte	12	1	3	2.2

Table 8. Number of observations, minimum, maximum, and average values for rank of the diatom group by volume at the nine intensive stations.

Station	n	Minimum	Maximum	Average
East Fork Hanging Woman Cr. near Birney	12	1	3	1.2
Hanging Woman Cr. near Birney	12	1	3	1.5
Hanging Woman Cr. near Quietus	10	1	2	1.5
Mizpah Cr. near Mizpah	4	1	2	1.8
Otter Cr. near Ashland	11	1	2	1.5
Pumpkin Cr. near Miles City	6	1	3	1.7
Rosebud Cr. near Kirby	10	1	2	1.5
Squirrel Cr. near Decker	9	1	2	1.6
Tongue R. near Pyramid Butte	12	1	2	1.6

Table 9. Number of observations, minimum, maximum, and average values for number of diatom species at the nine intensive stations.

Station	n	Minimum	Maximum	Average
East Fork Hanging Woman Cr. near Birney	12	28	55	42
Hanging Woman Cr. near Birney	12	25	77	50
Hanging Woman Cr. near Quietus	10	36	56	42
Mizpah Cr. near Mizpah	3	38	44	40
Otter Cr. near Ashland	10	26	48	35
Pumpkin Cr. near Miles City	5	17	41	28
Rosebud Cr. near Kirby	9	27	42	33
Squirrel Cr. near Decker	9	17	40	32
Tongue R. near Pyramid Butte	12	20	54	35

Table 10. Number of observations, minimum, maximum, and average values for diatom species diversity at the nine intensive stations.

Station	n	Minimum	Maximum	Average
East Fork Hanging Woman Cr. near Birney	12	2.15	4.84	3.98
Hanging Woman Cr. near Birney	12	2.57	5.37	4.27
Hanging Woman Cr. near Quietus	10	3.51	4.68	4.12
Mizpah Cr. near Mizpah	3	4.26	4.37	4.32
Otter Cr. near Ashland	10	2.89	4.52	3.62
Pumpkin Cr. near Miles City	5	1.72	4.20	2.97
Rosebud Cr. near Kirby	9	2.61	4.25	3.57
Squirrel Cr. near Decker	9	2.41	4.56	3.70
Tongue R. near Pyramid Butte	12	2.85	4.88	3.87

Table 11. Values for parameters generated by "semi-detailed readings" conducted according to Hohn (1961) on diatom samples collected from the nine intensive stations and Indian Creek during the week of August 5, 1979.

Station	Specific Conductance µmhos	Frustules Observed	Taxa Observed	Theoretical Universe	Taxa in Mode	% Specimens in Body of Curve
E. Fk. Hanging Woman Cr.	1357	11997	118	151	20	67
Hanging Woman Cr. near Birney	2580	21384	117	151	20	37
Hanging Woman Cr. near Quietus	4893	11760	117	151	20	69
Mizpah Cr.	3080	20160	97	129	17	40
Otter Cr.	3271	31455	112	144	19	26
Pumpkin Cr.	5998	13818	84	106	14	58
Rosebud Cr.	897	16764	93	121	16	47
Squirrel Cr.	2347	11044	104	136	18	73
Tongue R.	576	9538	152	197	26	84
Indian Cr.	662	27900	106	136	18	29

Table 12. Percent similarity of community samples (PS_c) for diatom collections taken from the nine intensive stations and Indian Creek during the week of August 5, 1979.

Station	1	2	3	4	5	6	7	8	9	10
1. E. Fk. Hanging Woman Cr.	--	28	28	8	16	21	18	26	28	24
2. Hanging Woman Cr. near Birney	28	--	43	26	57	25	24	33	22	27
3. Hanging Woman Cr. near Quietus	28	43	--	31	36	41	15	24	21	18
4. Mizpah Cr.	8	26	31	--	22	59	3	14	9	6
5. Otter Cr.	16	57	36	22	--	18	11	25	9	9
6. Pumpkin Cr.	21	25	41	59	18	--	6	15	18	15
7. Rosebud Cr.	18	24	15	3	11	6	--	30	27	60
8. Squirrel Cr.	26	33	24	14	25	15	30	--	31	8
9. Tongue R.	28	22	21	9	9	18	27	31	--	19
10. Indian Cr.	24	27	18	6	9	15	60	8	19	--
TOTALS	197	285	257	178	203	218	194	206	184	186

DISCUSSION

Bahls (*in* Miller *et al.*, 1978) reported a strong *inverse* relationship between salinity and diatom diversity for 91 surface waters in eastern Montana influenced by saline seep. Linear correlation coefficient (r) values computed for specific conductance and each of two diversity indexes (Margalef's and Simpson's), were -0.451 and -0.468. Both values were significant at the 1 percent level of probability.

These results are in contrast to the significantly *positive* correlations generated in the present study. The key to this discrepancy might be the different salinity ranges examined: 368 µmhos to 50,000 µmhos for the saline seep study and 239 µmhos to only 6,400 µmhos for the present study. Within the lower range, diatom diversity *appears* to be stimulated somewhat by salinity.

Bahls (1979) calculated Shannon-Weaver diatom diversity ($\bar{d}$) values for 80 streams from the eastern Montana saline seep study (Miller *et al.*, 1978). Fifty-three streams with TDS values less than 5,000 mg/l (about 7,500 µmhos) had an average $\bar{d}$ value of 3.34. Twenty-seven streams with TDS values greater than 5,000 mg/l (about 7,500 µmhos) had an average $\bar{d}$ value of 2.38. The average number of diatom species in these same two groups was 24 and 13, respectively. The paper concluded that excessive salinity from saline seeps will depress diatom diversity in Montana streams.

Patrick and Hohn (1956) have shown that the structure of diatom associations in brackish to salt water estuaries is very similar to that in a (hard water) river. However, the numbers of species composing the association "seem to be a little less." Stewart and Kantrud (1972) list the "normal range" for brackish waters as 5,000 µmhos to 15,000

μmhos specific conductance.

McKee and Wolf (1963) report that waters having specific conductance levels in excess of about 5,000 μmhos are, at best, of marginal utility for most beneficial uses, including domestic supply, industrial supply, irrigation, and stock and wildlife watering.

To protect waters suitable for such beneficial uses, including instream aquatic life, the Montana Legislature enacted a nondegradation policy into the Montana Water Quality Act [Sec. 75-5-303, M.C.A. 1979]:

> The board (of Health and Environmental Sciences) shall require:
> (1) that any state waters whose existing quality is higher than the established water quality standards be maintained at that high quality unless it has been affirmatively demonstrated to the board that a change is justifiable as a result of necessary economic or social development and will not preclude present and anticipated use of these waters; and
> (2) any industrial, public, or private project or development which would constitute a new source of pollution or an increased source of pollution to high-quality waters, referred to in subsection (1), to provide the degree of waste treatment necessary to maintain that existing high water quality.

In effect, this policy would prevent a developer from increasing the salinity level of a state water, except in the case of a successful appeal to the Board of Health and Environmental Sciences, and then only if the increase does not preclude present and anticipated beneficial uses.

CONCLUSIONS

1. Most streams in the study area supported healthy periphyton communities dominated by diverse associations of diatoms, indicating these streams and communities were relatively free from excessive stress, i.e., pollution.

2. Within the normal range of specific conductance values encountered in streams of the study area (239 µmhos to 6,400 µmhos), salinity did not appear to have an overriding or adverse effect on the structure of periphyton communities. Moreover, diatom diversity *appears* to be stimulated somewhat by salinity within this range.

3. Other work in Montana (Bahls, 1979) has demonstrated that specific conductance levels in excess of about 7,500 µmhos have a negative effect on diatom diversity, although the critical threshold level or range is not known.

4. Streams of the study area varied considerably in the composition of their diatom associations.

5. Within the normal range of salinity levels encountered in streams of the study area, other factors besides salinity influence the structure and composition of periphyton communities. Among these factors, prime candidates for further study are:

   - stream order
   - season (time of year)
   - substrate and period of colonization

- other algae
- turbidity/TSS/light transmission
- flow regime (perennial/intermittent/ ephemeral)
- temperature
- nutrients
- organic pollution (BOD/TC/DO)
- common ions (monovalent:divalent ratio)
- toxics (heavy metals/pesticides)
- upstream impoundments
- stream gradient/current velocity
- invertebrates (grazing)
- primary production

RECOMMENDATIONS

1. For new developments, apply management practices and provide waste treatment necessary to maintain existing salinity levels in streams of the study area. This is especially important for streams with salinity levels already marginal for present and anticipated beneficial uses.

2. Establish long-term salinity and biological monitoring stations at strategic locations on key streams in the study area, and
   a. Once annually, commencing with resource development, determine the pattern of the diatom flora using the semi-detailed method of Hohn (1961) or the detailed method of Patrick *et al.* (1954); and
   b. Apply appropriate statistical analyses to determine whether observed year-to-year variations are within acceptable limits.

3. Pursue research to determine the critical threshold level or range above which salinity will impair the structure of periphyton communities in streams of the study area.

4. Pursue research to determine what influence other factors besides salinity may have on the structure and composition of periphyton communities in streams of the study area.

5. Pursue research to establish the environmental requirements and pollution tolerances of major diatom taxa inhabiting streams of the study area.

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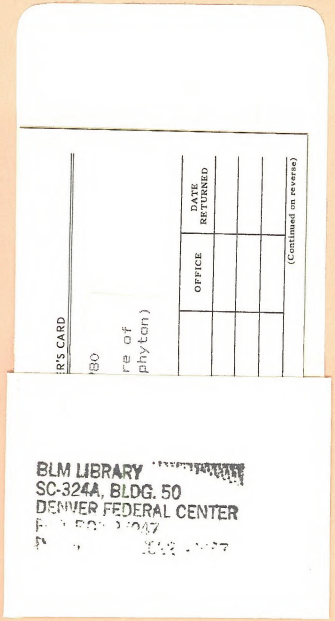
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